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ENHANCING TOUGHNESS OF POLYPROPYLENE AND POLYSTYRENE –APPLICATION OF STYRENE-b-ETHYLENE-alt-BUTYLENES-b-STYRENE

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Abstract. Since toughness is an important mechanical property, impact modifiers are widely used to enhance the impact properties of many thermoplastics. This paper focused on the effectiveness of styrene-b-ethylene-alt-butylenes-b-styrene (SEBS) as an impact modifier in polypropylene (PP) and polystyrene (PS). In this study, blends of PP/SEBS and PS/SEBS were prepared using single screw extruder. The concentration of SEBS varied from 5 to 20phr of polymer for both PP and PS. After mixing and pelletizing, the dried pellets were injection molded and tested for mechanical properties. With increasing SEBS content, the increase in impact properties is more significant in PP/SEBS blends compared to PS/SEBS blends. Tensile test showed a slightly decrease of tensile strength for both blends. For PP/SEBS blends of 15phr SEBS content and above, no sample break was observed during the tensile test. A decrease in flexural modulus of both blends with increasing SEBS contents was observed, with a more siginificant decrease in PS/SEBS blends. Overall, SEBS is shown to be more effective as an impact modifier in PP compared to PS.

Key Words: PP, PS, SEBS; melt blending; impact properties

1.0 INTRODUCTION

Being a commodity polymer, polypropylene (PP) has a wide range of domestics and industrial applications. PP has been widely used for injection molding applications. Although it has a remarkable combinations of physical properties, the main deficiency of PP is its poor impact resistance, particularly at low temperature and high loading rate conditions [1]. Polystyrene (PS) is a thermoplastic resin used in many applications because of its low cost and easy processability. PS is also a brittle polymer even at ambient temperature due to its high glass transition temperature (Tg) [2]. Recently, the blending of polymers with elastomers has been widely studied with the objective of enhancing the impact strength of polymers [3-5]. These elastomers act as impact modifiers which dissipate impact energy by intensified stable crazing which is triggered in the stress field near the rubber particles in their polymer matrix. The ethylene-propylene copolymer (EPM) and the ethylene-propylene-diene terpolymer (EPDM) are often used as impact modifiers for PP. While for PS, rubber particles has been incorporated to the matrix and leading to HIPS and ABS [6].

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Recently, Sani Amril *et al.* investigated the effects of SEBS, a type of thermoplastics elastomer, on the mechanical properties of PS rich PS/PP blends [7]. The results showed that the mechanical properties of the PS/PP blends are dependent on blend composition (ratio of PS/PP) and SEBS contents. The impact strength and elongation at break of the PS/PP blends increased with SEBS content at the expense of tensile strength and flexural modulus. The improvements of impact strength and elongation at break with the addition of SEBS are due to the improved interfacial adhesion between the dispersed phase (PP) and matrix phase (PS). The effectiveness of SEBS in enhancing the blends was found to depend on the blend composition. In this research, the effectiveness of SEBS as impact modifiers in neat PP and PS was studied and compared. The effects on other tensile and flexural properties were also studied.

2.0 EXPERIMENTAL

2.1 Materials

The PP grade used in this study was injection molding grade TITANPRO 6431 homopolymer polypropylene with melt index of 7.5 g /10min. This resin was supplied by Titan Himont Polymers (M) Sdn. Bhd. PS with general purpose grade GPPS HH-30 was used and being supplied by Petrochemicals (M) Sdn. Bhd. The Impact modifier used in this research was a thermoplastic elastomer SEBS (Kraton 1652G), supplied by Tiram Kimia Sdn Bhd.

2.2 Blending

The compositions of the blends prepared in this study were listed in Table 1 with the SEBS varied from 5 to 20phr. To obtain uniform mixed compositions, the materials were firstly physically mixed using a tumbler mixer for about 5 to 10 minutes. The uniformly mixed compositions were then melt blended in a single screw extruder. Extrusion was done in a 40mm TANABE model extruder with screw diameter 40mm. It was conducted at a screw speed of 55 rpm with barrel temperatures 190, 200, 210, 220 and 230°C, from feeding zone to die zone. The extruded strands then were immersed in water bath at temperature of 50°C and then pelletized. The pellets were then injection molded to standard dimensions according to ASTM standards. Using Mitsubishi 160MJ injection molding machine, PP was moulded at temperatures of 190°C at the feeding zone to 200°C at the die zone. The temperatures for moulding PS were from 200°C at the feeding zone to 235°C at the die zone. The mold temperature was 40°C for both polymers and the injection cycle was about 45 and 50 seconds for PP and PS, respectively.

3.0 MECHANICAL MEASUREMENT

3.1 Tensile Test

Tensile Test was carried out according to ASTM D 638-96 on an Instron Model 556 Universal Testing machine at ambient temperature (25 $\pm$ 2°C). The strain rate was 50 mm/min with gauge length 60 mm. The values reported are average of five samples tested.

3.2 Flexural Test

Flexural test was carried out on an Instron Model 556 Universal Testing Machine at ambient temperature (25 $\pm$ 2°C) according to ASTM D 790-86. The support span was fixed at 100 mm with crosshead speed 3 mm/min. The values reported are average of five samples tested.

Table 1 Blend formulations (SEBS are based on part per hundred (phr) polymers).

Sample code	PP (%)	PS (%)	SEBS (phr)
PS00	0	100	0
PS01	0	100	5
PS02	0	100	10
PS03	0	100	15
PS04	0	100	20
PP00	100	0	0
PP01	100	0	5
PP02	100	0	10
PP03	100	0	15
PP04	100	0	20

3.3 Impact Test

Notched Izod Impact test was carried out according to ASTM D 256-93a on a Toyoseiki Pendulum Impact Testing Machine at ambient temperature (25 $\pm$ 2^{o}C). The impact specimens were notch (45^{o}) to a depth of 2.6 mm. The reported values are average of five samples tested.

4.0 RESULTS AND DISCUSSION

4.1 Tensile Properties

The effects of the SEBS contents on the tensile and elongation at break of PP/SEBS and PS/SEBS blends are shown in Figure 1 and 2, respectively. The result indicates that tensile strength of both blends were slightly decrease with increasing SEBS contents. The result also shows that tensile strength of PS is higher than PP. The presence of bulky pendant phenyl rings in the PS structure make the chain slippage becomes more difficult during the deformation resulting in a higher tensile strength than PP. This bulky side groups also reduce their ductility. This is illustrated by the elongation at break of PS being very much lower than PP (Fig. 2). The elongation at break was observed to increase with increasing SEBS content. However the increase of elongation at break with increasing SEBS is lower for PS compared to PP. At 10 phr SEBS content and above, no samples breakages was observed indicating the PP blends to be very ductile. The initial part of stress-strain curve is fairly linear, where the entire specimen stretches uniformly. However, necking was observed after the yield point.

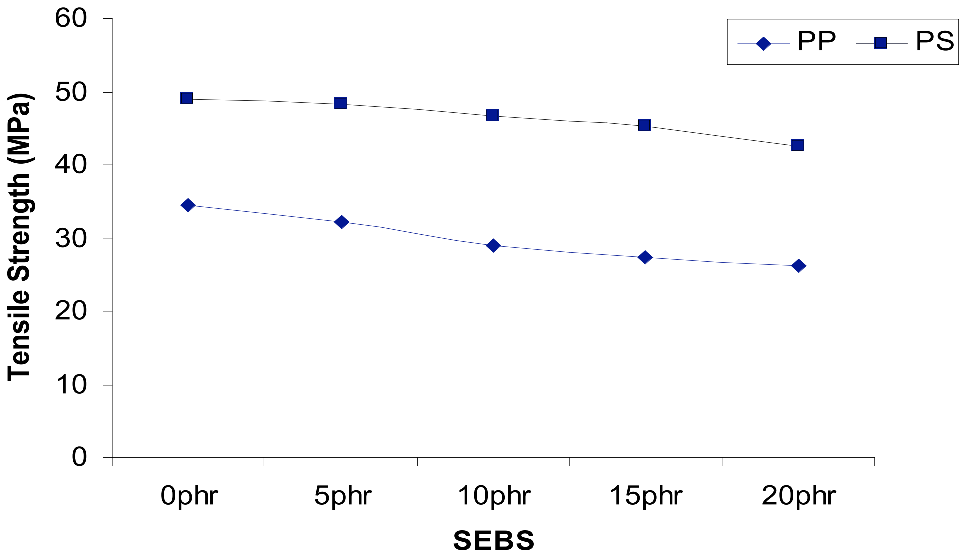

Figure 1 Effect of SEBS content on tensile strength of PS/SEBS and PP/SEBS blend

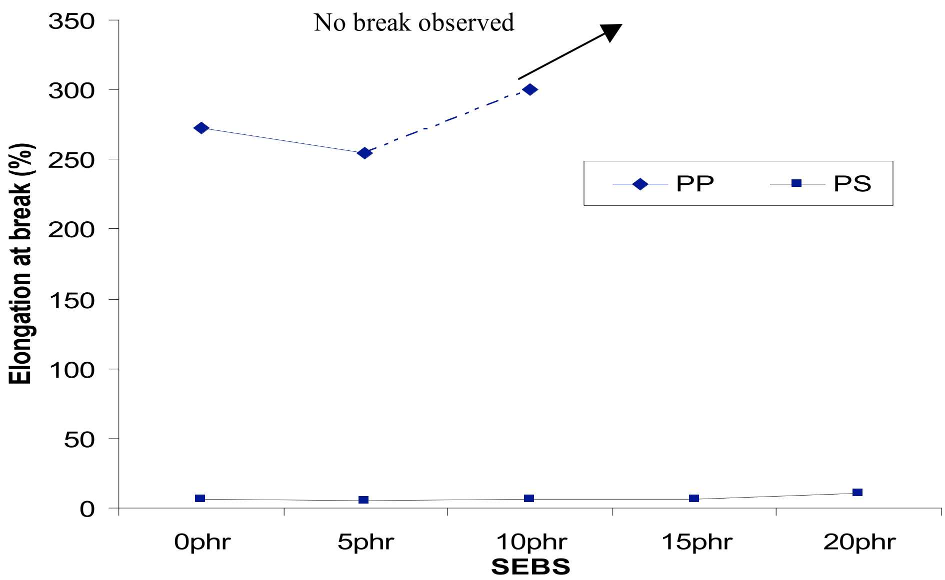

Figure 2 Effect of SEBS content on Elongation at break of PP and PS

4.2 Flexural Properties

The effects of SEBS content on flexural strength for both PS and PP are shown in Figure 3. The result shows that flexural strength of PS is nearly 2.5 times higher than PP. It is interesting to note that the addition of 5 phr SEBS into PS shows slightly higher values than that of neat PS, followed by a decreasing trend. The flexural strength of PP blends decreased gradually with the increase in SEBS concentration.

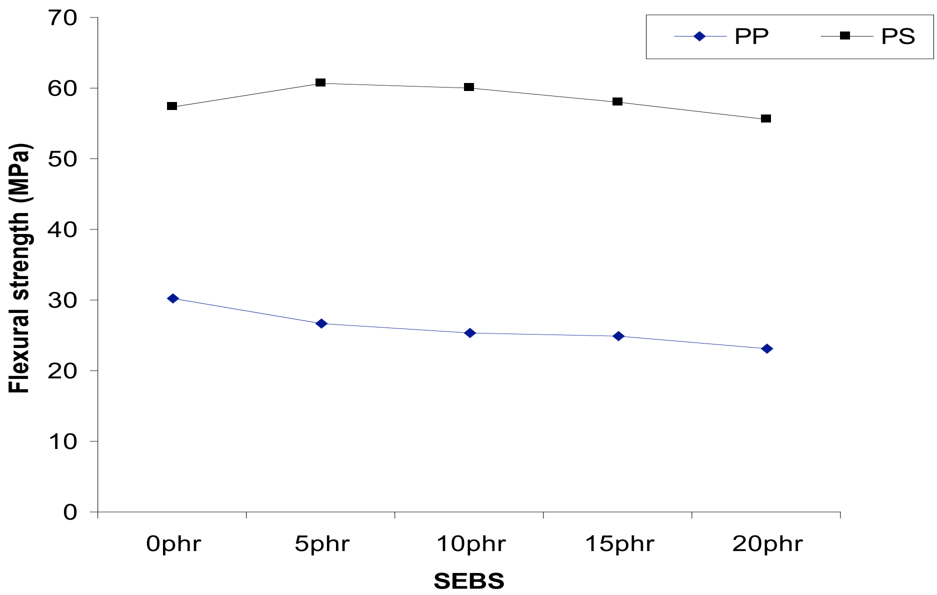

Figure 3 Effect of SEBS content on Flexural strength of PP and PS

Figure 4 illustrates that the flexural modulus which is an indication of stiffness, decreased with the increase in SEBS concentration for both PP and PS. The decrease was found to be more significant in PS compared to PP.

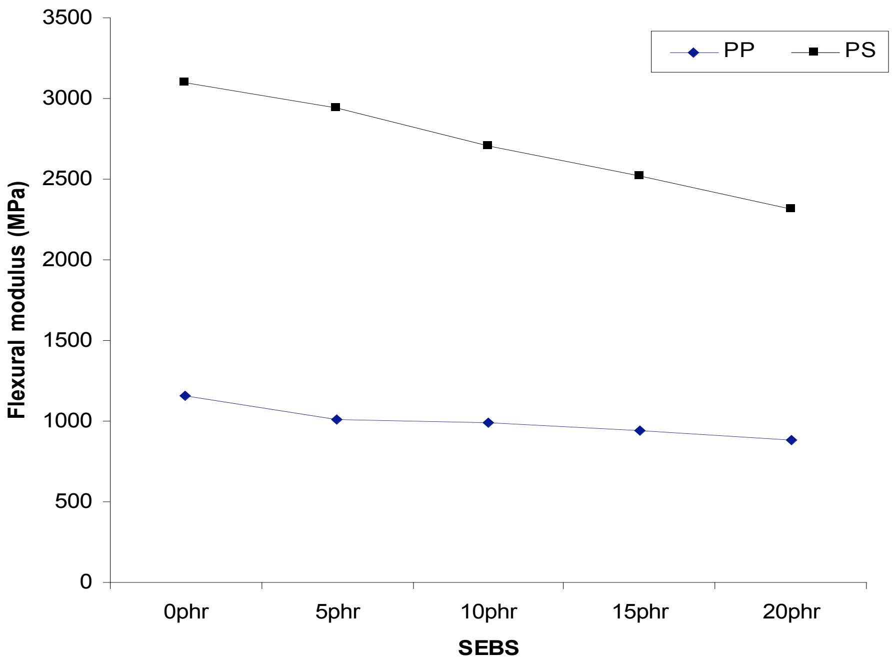

Figure 4 Effect of SEBS content on Flexural Modulus of PP and PS

4.3 Impact Properties

Figure 5 illustrates the notched Izod impact strength of PP/SEBS and PS/SEBS blends. The figure shows that the impact strength of both blends increased with increasing SEBS contents.

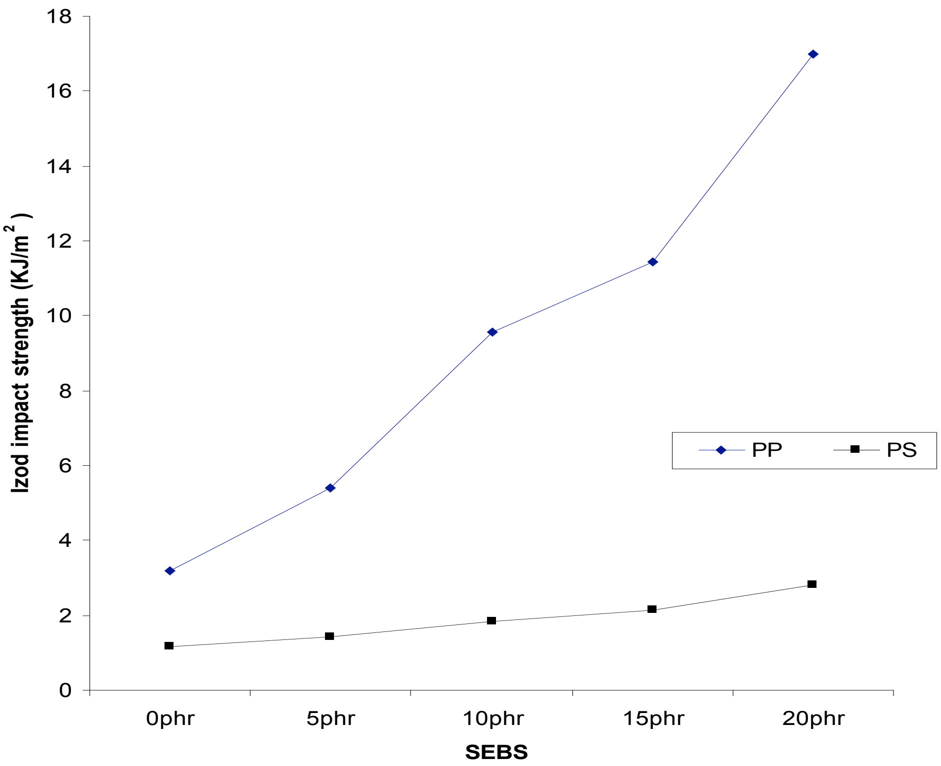

Figure 5 Izod impact strength of PP/SEBS and PS/SEBS blends.

A more significant increase in impact strength was observed with an increase in SEBS for PP/SEBS blends compared to PS/SEBS blends. The more significant increase can be explained in terms of good interfacial adhesion between PP and SEBS. The interactions arise from the chemical structure of PP that is close to the mid-block of SEBS [8]. Accordingly, SEBS can diffuse into the PP phase, forming small micelles. The inter-diffusion between the EB block of SEBS and PP contributes to a certain degree of improvement in the interfacial adhesion for the PP/SEBS blend [9]. Gacther *et al.* concluded that when the final articles made from impact modified polymers are subjected to shock and impact stress the mechanical energy imparted is initially absorbed by the matrix which is the hard phase [10]. If brittle fracture is to be prevented, the energy must be transferred and diverted to the enclosed elastomeric phase. Therefore, in the present study, there is a strong possibility that the stress imparted was being diverted to SEBS in the blends.

5.0 CONCLUSIONS

A study has been conducted to determine the effects of SEBS on mechanical properties of PP and PS. From the results obtained, it has been shown that impact strength for both blends increased with increasing SEBS contents. Impact properties of PP/SEBS blends improved significantly due to the good interfacial adhesion between SEBS and PP. Ductility as indicated by elongation at break also increased when SEBS was incorporated into both blends. Similar trend was also observed whereby the increase in ductility is more significant in PP. The increase in impact strength and ductility were at the expense of stiffness and strength. From the stress-strain curve, the tensile stress decreased after the yield point which indicated the occurring of necking. Overall, SEBS is shown to be a more effective impact modifier in PP compared to PS.

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